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# Development of Rewritable Dual-layer Phase-change Optical Disks

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## Abstract

Dual-layer optical disks comprised of two data layers were developed to study readout/write/erase characteristics. This disk was composed of recording layer 1 and 2, of high transmittance and high reflectivity, respectively. Layer 1 and 2 of 15 and 20 nm increase transmittance and reduce writing power for recording. Only 1.5 mW laser power was sufficient for readout, 9 and 16 mW was required for recording on recording layer 1 and 2, respectively. These dual-layer disk can double data capacity on a disk substrate.

## 1. Introduction

Digital versatile disks (DVD) are now emerging in the market. Many advanced recording technologies, such as mark-edge recording and land/groove recording, have already been proposed for DVD-RAM disks in increasing their recording density and capacity. Volumetric optical disks can increase the storage capacity by using multiple data layers for storage where the data are recorded on each layer of a multi-layer stack<sup>1,2</sup>, respectively. In this paper, we present the study of write/erase/read performance of a dual-layer erasable optical disks using phase change recording media.

## 2. Design of disk structure and thermal simulation

The dual-layer optical disk was composed of two polycarbonate substrates<sup>3</sup>, which were coated with layer 1 and layer 2, as shown in Fig. 1, respectively. Layer 1 is the first data layer impinged by laser beam while layer 2 is the second layer. The data layers of the disk were spaced from each other by an UV resin layer of 40  $\mu\text{m}$  in thickness.

The transmittance of the layer 1 must be sufficiently large in order to focus, track and record on the layer 2 through the layer 1. Thus, the disk structure with no metallic reflective for the layer 1, which is in a "High-to-Low" structure, where the reflectivity decreases in accordance with recording process (crystalline to amorphous state). Since metallic cooling layer accelerates phase change material in temperature descending during recording process, recording performance of layer 1 of no metallic cooling layer will be lower.

For the layer 2, reflectivity must be high, because the incident laser beam is inevitably reduced by the light absorption and reflection from the layer 1. In order to increase the optical efficiency, the transmittance is set to zero. Thus, a "Low-to-High" structure is adopted. Besides, owing to write power of laser pulse is proportional to thickness of recording media, proper thickness of recording media is necessary. Therefore, schemes to meet the write power limit of commercial disk drive (less than 20 mW) by using thin active layer are necessary.

By thin-film theorem and metric optics, the reflectivity, transitivity, and absorption coefficient of the two recording layers were calculated. A very simple 3 and 4 layers disk structure for recording layer 1 and 2 that meets the condition mentioned above was selected. Optical design of reflection, absorption and transmittance of recording layer 1 and 2 is shown in Fig. 2.

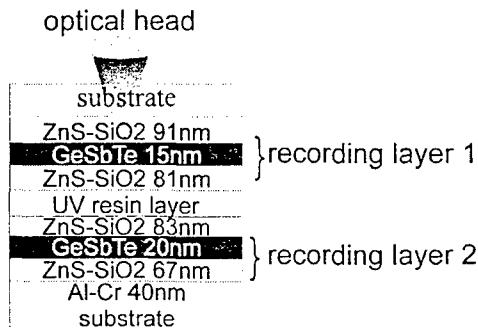


Fig. 1 Schematics of a dual layer optical disk structure

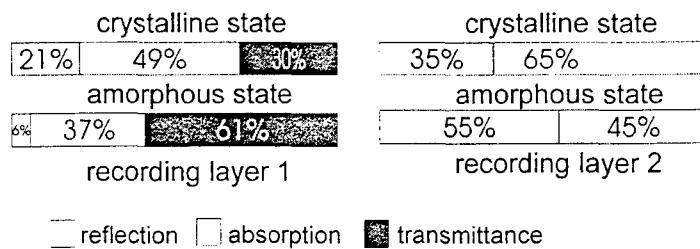


Fig. 2 Reflection, absorption and transmittance of layer 1 and 2 of a dual-layer optical disk

A gaussian-distributed diffraction limited spot impinged perpendicular on a disk of a multi-layered thin film structure was then analyzed by thermal simulation. When the light penetrates the multi-layer structure, its energy is absorbed by the recording layer, and converted into heat. The heat diffuses to neighbor area and the other layers. The temperature distributions was calculated by a thermal simulation program "Temprofile"<sup>4</sup> to ensure that quench rate was high enough for writing by simulation. The quench rate of layer 1 and 2 is 6 and 9 °C/ns, respectively, as shown in Figs. 3, which can meet the writing requirement<sup>5</sup>.

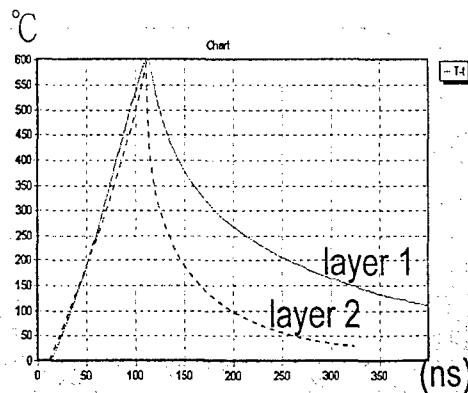


Fig. 3 Simulated quench rate of layer 1 and 2 of dual layer optical disk

### 3. Experiment

Disks of recording layers 1 and 2, were deposited on a u-grooved 120-mm diameter polycarbonate substrate separately, then glued together by an ultraviolet-light-cured resin. The parameters of the read and write measurement are listed in Table 1. Write pulse patterns shown in Fig. 4 were frequency-modulated between 3 and 9 MHz; peak laser power was modulated between 0 and 20 mW.

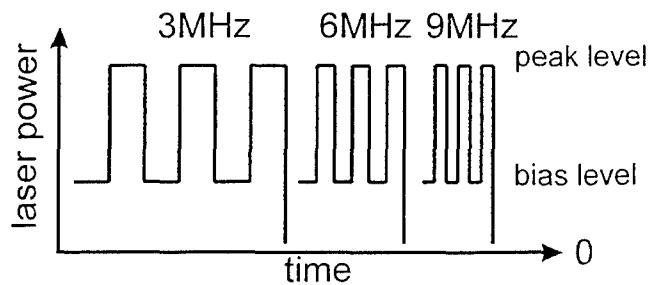


Fig. 4 Write pulse waveform used in this experiment

Table 1 Read/write parameters

Linear velocity	7.33m/s
Laser wave length	660 nm
Numerical Aperture (NA)	0.6
Read power	1.5 mW
Recording waveform	as shown in Fig. 4

### 4. Results and discussions

CNR as a function of laser peak power for layer 1 and 2 was shown in Fig. 5. At writing frequency of 3 MHz, corresponding to 1.2  $\mu$ m in mark length, the peak power giving a CNR of 45 dB was 9 mW for layer 1 and 13 mW for the layer 2. The eraseability better than 35 dB was obtained at erase laser power of 6 and 9 mW for layer 1 and 2, respectively.

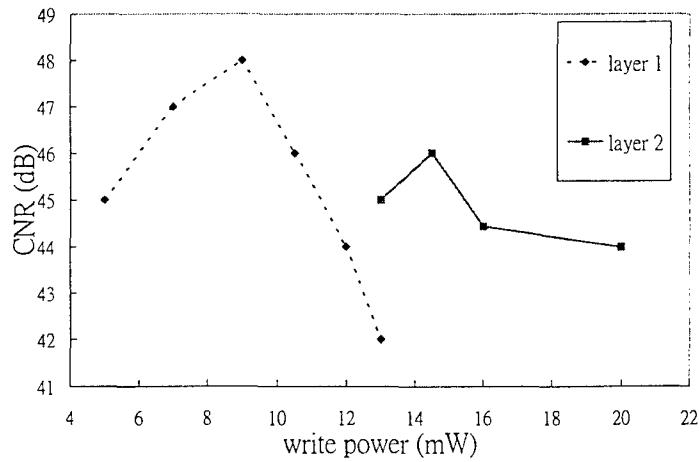


Fig. 5 CNR as a function of write power for layer 1 and 2 at recording frequency of 3 MHz

CNR as a function of laser peak power for layer 1 and 2 is shown in Fig. 6. The peak CNR is at power of 9 mW for layer 1 and at 13 mW for the layer 2 at recording frequency of 7 MHz, corresponding to 0.52  $\mu$ m in mark length. Thin recording layers were adopted in dual-layer optical disk recording in, to increase write power sensitivity, i.e. too low a write power won't be adequate for phase change media and too high write power will destroy the phase change material or disk track. Therefore, optimized write power can achieve higher CNR on this dual-layer disk.

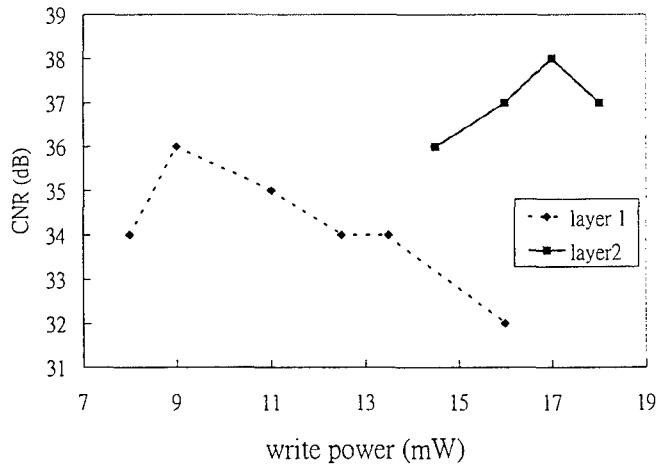


Fig. 6 CNR as a function of write power for layer 1 and 2 at recording frequency of 7 MHz

CNR as a function of mark size of layers 1 and 2 and a commercial DVD-RAM disk is shown in Fig. 7. CNR at mark size of 0.6  $\mu$ m higher than 43 dB is obtained on both layers. CNR of the dual-layer disks is very close to that of single layer DVD-RAM disks.

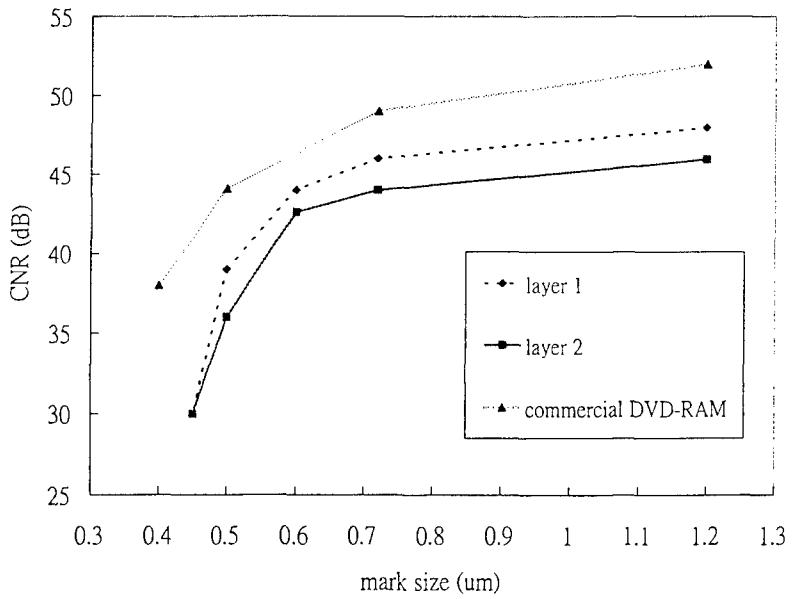


Fig. 7 CNR as a function of mark size of layers 1, layer 2, and a commercial DVD-RAM disk

To examine the effect of layer 1 on the writing performance of layer 2, a single layer disk, "a comparison disk" with the same disk structure as layer 2, was prepared. CNR as a function of write power for comparison disk and layer 2 was shown in Fig. 8. The peak CNR is at power of 8 mW for comparison disk and at 15 mW for the layer 2 of dual-layer disk at recording frequency of 3 MHz, implying that writing power is about double to compensate the optical energy lose in transmitting through the layer. Dependence of the CNR on the mark size for comparison disk and layer 2 of dual-layer disk as shown in Fig. 9, where CNR write power of 10 and 16 mW are almost the same. According to the simulation, transmittance of layer 1 approximate 60%, which agrees with peak power requirement (10 and 16 mW) measured experimentally.

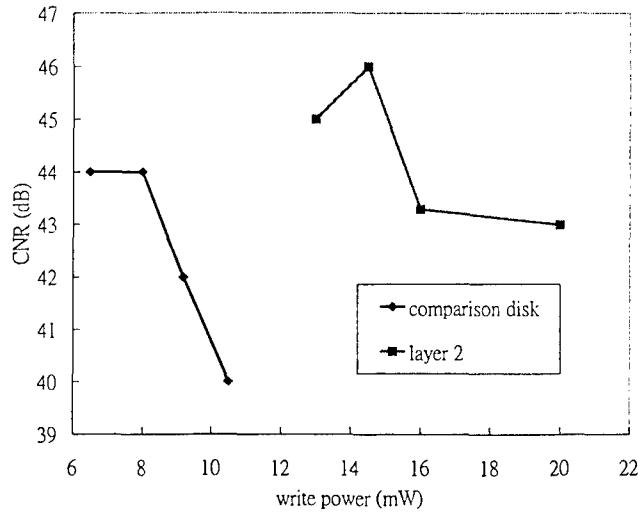


Fig. 8 CNR as a function of write power for comparison disk and layer 2

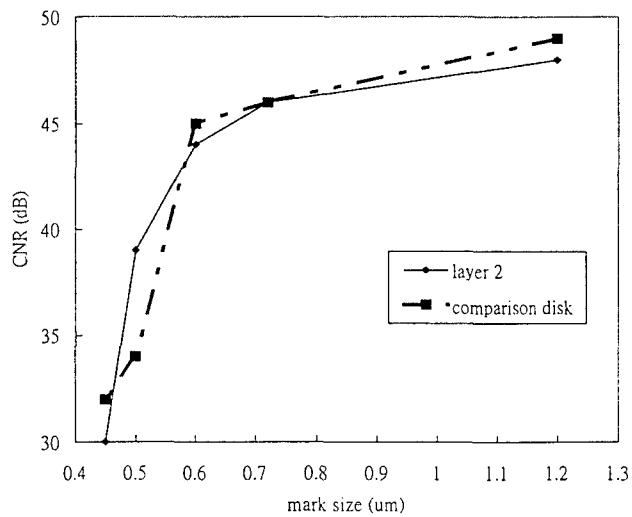


Fig. 9 CNR as a function of the mark size for comparison disk and the layer 2 of dual-layer disk

## 5. Conclusion

The thermal and optical simulations facilitate the design of dual-layer erasable optical disks using phase change recording media with high transmittance and high reflectivity recording layers, respectively. CNR of 0.6  $\mu\text{m}$  mark size on both layers was better than 45 dB at read power of 1.5 mW. The results suggest that dual-layer disks can be promising for double data capacity on a disk substrate.

## Acknowledgement

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